# APPENDIX

TO ACCOMPANY

# SURVEY REPORT

FOR

# NAVIGATION, FLOOD CONTROL

AND

# WATER POWER

# MERRIMACK RIVER

## MASSACHUSETTS AND NEW HAMPSHIRE







AUTHORIZED BY THE
RIVER & HARBOR ACT
APPROVED JUNE 20, 1938.

U.S. ENGINEER OFFICE
BOSTON, MASS.
APRIL 1, 1940.

COPY NO. 1

SECTION A

MERRIMACK SURVEY REPORT DATED APRIL 1, 1940
APPENDIX - SECTION A
DESIGN AND COST DATA

1. West Peterboro Reservoir.- The proposed West Peterboro Reservoir is located in Hillsboro and Cheshire Counties, New Hampshire. The dam site is about one-half mile upstream from the village of West Peterboro, N.H., on Nubanusit Brook, a tributary of the Contoocook River, about 35 miles southwest of Concord, N.H., and 60 miles northwest of Boston, Mass.

2. Reservoir and Outlet Capacity.- a. Initial Stage.- The reservoir is designed to control a flood of about the magnitude of that of March 1936, having a flood control storage capacity of 16,000 acre-feet with the spillway crest at elevation 946. (Area and capacity curves are shown on Plate A1.) This capacity is equivalent to 6.8 inches of run-off over the 44 square miles of drainage area controlled. The maximum outlet discharge for flood control operation will be 650 c.f.s. with the pool at spillway crest elevation 946. Additional outlet capacity will be provided to give a total discharge at elevation 946 of 1300 c.f.s., making it possible to empty the reservoir from full pool in about 10 days.

b. Ultimate Development.- The flood control storage capacity of 16,000 acre-feet and the discharge capacities for flood control operation and emptying purposes will be retained in the ultimate development.

3. Spillway Requirements.- a. Initial Stage.- The spillway will be provided at a saddle about 3.5 miles north of the dam site and will consist of a cut 2800 feet long to discharge into Ferguson Brook, a tributary of the Contoocook River. A concrete control weir 87 feet

long will be located near the downstream end of the cut. The spillway has a discharge capacity of 18,000 c.f.s. at pool elevation 962, leaving a freeboard of 5 feet from the top of the earth dam. The surcharge storage is equivalent to 9.3 inches over the drainage area. The computed spillway flood was based on maximum rainfall values for the Merrimack Basin as derived for approved reservoir projects in this vicinity. A spillway design flood, 50 per cent greater than the computed spillway flood, was routed through the reservoir starting with pool at spillway lip elevation and assuming all outlets inoperative.

b. Ultimate Development.- For the ultimate project a concrete, free overfall weir, 150 feet long, with crest at elevation 968 will be located in the spillway cut upstream from the initial spillway weir. The ultimate spillway will pass the spillway design flood with a maximum pool elevation of 979, leaving 5 feet of freeboard from the top of the ultimate earth dam.

4. Reservoir Area.- a. Initial Stage.- With spillway crest at elevation 946, the reservoir will have an area of 900 acres, consisting of about 60 per cent of wooded area, 17 per cent in pasture and meadow, and 23 per cent tillable land. The area affected is sparsely populated, involving fewer than 40 persons. There are no railroads in the area, and only 1.7 miles of highways and a small amount of power and telephone line relocation will be necessary.

b. Ultimate Development.- At pool elevation 968, considered for possible ultimate development, an additional area of 1040 acres is affected, including a physical education school, affiliated with Boston University, known as "Sargent's Camp", valued at $120,000. Relocation of an additional 3/4 mile of highway and some improvement of existing roads will be required.

5. Surveys and Exploration.- Topographic surveys were made of the dam site and saddle spillway areas. Bedrock conditions at the dam site were determined by observation of limited rock outcrops in the river bed and by seismic investigations on both abutments. Bedrock relations in the spillway area were determined by observation of outcrops and the drilling of three holes along the general alignment of the channel. The locations of suitable materials for the construction of the embankment and production of concrete aggregates and the character of the overburden at the dam site were determined by overburden exposures and auger holes.

6. Description of Proposed Dam.- a. Initial Stage.- The proposed initial construction will consist of a rolled earth fill embankment 610 feet long, with a top width of 25 feet at elevation 967, a maximum height of 83 feet, and side slopes of 1 on 3. Sections showing pervious and impervious features, slope treatment, and the design treatment to permit future raising of the dam are shown on Plate A1. The outlet works from the gate structure to the stilling basin will be located on rock and will consist of a flood control outlet controlled by two vertical gates with a total area of about 33 square feet and one 9-foot diameter steel-lined penstock with provision for future gate installation in a combined gate tower. The stilling basin will be located downstream far enough in the initial stage to permit raising the dam 17 feet in the future.

b. Ultimate Development.- The additional construction required for the ultimate development will consist of raising the embankment and gate tower 17 feet and extension of the penstock to the end of the stilling basin, a distance of 200 feet.

7. A detailed estimate of the cost of West Peterboro Reservoir constructed initially for flood control with provision for the future addition of conservation storage and the development of power is as follows:

I. RESERVOIR COSTS

| | Quantity | Unit Cost | Cost |
|---|---|---|---|
| Land Acquisition | lump sum | | $ 23,800 |
| Buildings | lump sum | | 11,600 |
| Utility Relocation | lump sum | | 4,600 |
| Highway Relocation | lump sum | | 50,000 |
| Water Rights | | | 70,000 |
| SUB-TOTAL - RESERVOIR COSTS | | | $ 160,000 |
| Engineering, Appraisals, Overhead & Contingencies 35%± | | | 56,000 |
| TOTAL RESERVOIR COSTS | | | $ 216,000 |

II. CONSTRUCTION COSTS

(a) DAM AND OUTLETS

| | Quantity | Unit Cost | Cost |
|---|---|---|---|
| Stream Diversion and Pumping | lump sum | | $ 20,000 |
| Clearing and Grubbing | lump sum | | 3,500 |
| Stripping Dam Site | 15,000 c.y. | $ .40 | 6,000 |
| Common Excavation | 25,000 c.y. | .50 | 12,500 |
| Rock Excavation | 3,000 c.y. | 2.50 | 7,500 |
| Impervious Borrow | 113,000 c.y. | .50 | 56,500 |
| Pervious Borrow | 100,000 c.y. | .55 | 55,000 |
| Rolled Fill - Impervious | 105,000 c.y. | .14 | 14,700 |
| Rolled Fill - Pervious | 110,000 c.y. | .14 | 15,400 |
| Rock Fill and Dumped Riprap | 18,000 c.y. | 1.00 | 18,000 |
| Riprap - Hand-placed | 1,000 c.y. | 2.50 | 2,500 |
| Sand and Gravel Backing | 10,000 c.y. | 1.50 | 15,000 |
| Topsoil and Seeding | lump sum | | 2,000 |
| Drilling and Grouting | lump sum | | 2,000 |
| Line Drilling | 6,000 s.f. | 1.00 | 6,000 |
| Concrete - Outlet Works | 6,600 c.y. | 17.00 | 112,200 |
| " - Gravity Walls | 1,900 c.y. | 13.00 | 24,700 |
| Reinforcing Steel | 450,000 lb. | .05 | 22,500 |
| Penstock Lining | 105,000 lb. | .10 | 10,500 |
| Trash Bars | lump sum | | 3,000 |
| Gates, Guides, Hoists, Oper. Eqpt. | lump sum | | 15,000 |
| Crane | lump sum | | 5,000 |
| Access Road | lump sum | | 5,000 |
| Miscellaneous Items | | | 7,500 |
| TOTAL - DAM AND OUTLETS | | | $ 442,000 |

(b) SADDLE SPILLWAY

| | Quantity | Unit Cost | Cost |
|---|---|---|---|
| Clearing | 11 acres | $ 125.00 | $ 1,375 |
| Excavation - Earth and Rock | 260,000 c.y. | 1.20 | 312,000 |
| Concrete for Spillway Weir | 1,700 c.y. | 15.00 | 25,500 |
| Riprap | 1,800 c.y. | 2.00 | 3,600 |
| Miscellaneous Items | lump sum | | 5,525 |
| TOTAL - SPILLWAY COST | | | $ 348,000 |
| TOTAL - DAM, OUTLETS AND SPILLWAY | | | $ 790,000 |
| (c) RESERVOIR CLEARING | lump sum | | 13,000 |
| SUB-TOTAL - CONSTRUCTION COST | | | $ 803,000 |
| Engineering, Inspection, etc. 35%± | | | 281,000 |
| TOTAL CONSTRUCTION COST | | | $ 1,084,000 |
| TOTAL ESTIMATED INITIAL COST | | | $ 1,300,000 |

8. A detailed estimate of the additional costs necessary for the ultimate development is as follows:

## I. RESERVOIR COSTS

| | Quantity | Unit Cost | | Cost |
|---|---|---|---|---|
| Land Acquisition | lump sum | | $ | 55,450 |
| Buildings | lump sum | | | 161,400 |
| Utility Relocation | lump sum | | | 5,000 |
| Highway Relocation | lump sum | | | 60,000 |
| Miscellaneous Items | lump sum | | | 7,000 |
| SUB-TOTAL RESERVOIR COSTS | | | $ | 288,850 |
| Engineering, Inspection, Overhead & Contingencies, 35%± | | | | 101,350 |
| TOTAL RESERVOIR COSTS | | | $ | 390,200 |

## II. CONSTRUCTION COSTS

### (a) DAM AND OUTLETS

| | Quantity | Unit Cost | | Cost |
|---|---|---|---|---|
| Clearing and Grubbing | lump sum | | $ | 1,500 |
| Stripping Dam Site | 9,000 c.y. | $ .40 | | 3,600 |
| Common Excavation | 8,000 c.y. | .50 | | 4,000 |
| Rock Excavation | 200 c.y. | 3.50 | | 700 |
| Impervious Borrow | 26,000 c.y. | .55 | | 14,300 |
| Pervious Borrow | 127,000 c.y. | .60 | | 76,200 |
| Rolled Fill - Impervious | 24,000 c.y. | .15 | | 3,600 |
| Rolled Fill - Pervious | 125,000 c.y. | .15 | | 18,750 |
| Rock Fill & Dumped Riprap | 13,000 c.y. | 2.00 | | 26,000 |
| Riprap - Hand-placed | 200 c.y. | 3.00 | | 600 |
| Sand and Gravel Backing | 7,000 c.y. | 1.50 | | 10,500 |
| Topsoil and Seeding | lump sum | | | 2,700 |
| Line Drilling | 1,600 s.f. | 1.00 | | 1,600 |
| Concrete - Miscellaneous | 900 c.y. | 20.00 | | 18,000 |
| Reinforcing Steel | 50,000 lb. | .06 | | 3,000 |
| Penstock Lining | 60,000 lb. | .10 | | 6,000 |
| Replacing Hoists, Operating Equipment and Crane | lump sum | | | 8,000 |
| Access Road | lump sum | | | 6,000 |
| Miscellaneous Items | | | | 7,950 |
| TOTAL - DAM AND OUTLETS | | | $ | 213,000 |

### (b) SADDLE SPILLWAY COSTS

| | Quantity | Unit Cost | | Cost |
|---|---|---|---|---|
| Clearing | lump sum | | $ | 200 |
| Excavation - Earth and Rock | 1,000 c.y. | $ 1.20 | | 1,200 |
| Concrete - Spillway and Piers | 2,000 c.y. | 19.50 | | 39,000 |
| Bridge | lump sum | | | 15,000 |
| Riprap | 2,000 c.y. | 2.00 | | 4,000 |
| Miscellaneous Items | | | | 3,600 |
| TOTAL - SPILLWAY COSTS | | | $ | 63,000 |

### (c) RESERVOIR CLEARING

| | Quantity | Unit Cost | | Cost |
|---|---|---|---|---|
| Flood Control | lump sum | | $ | 8,000 |
| Conservation | lump sum | | | 103,500 |
| TOTAL - RESERVOIR CLEARING | | | $ | 111,500 |
| SUB-TOTAL - CONSTRUCTION COST | | | $ | 387,500 |
| Engineering, Inspection, etc., 35%± | | | | 135,300 |
| TOTAL CONSTRUCTION COST | | | $ | 522,800 |
| TOTAL ESTIMATED DEFERRED COST | | | $ | 913,000 |

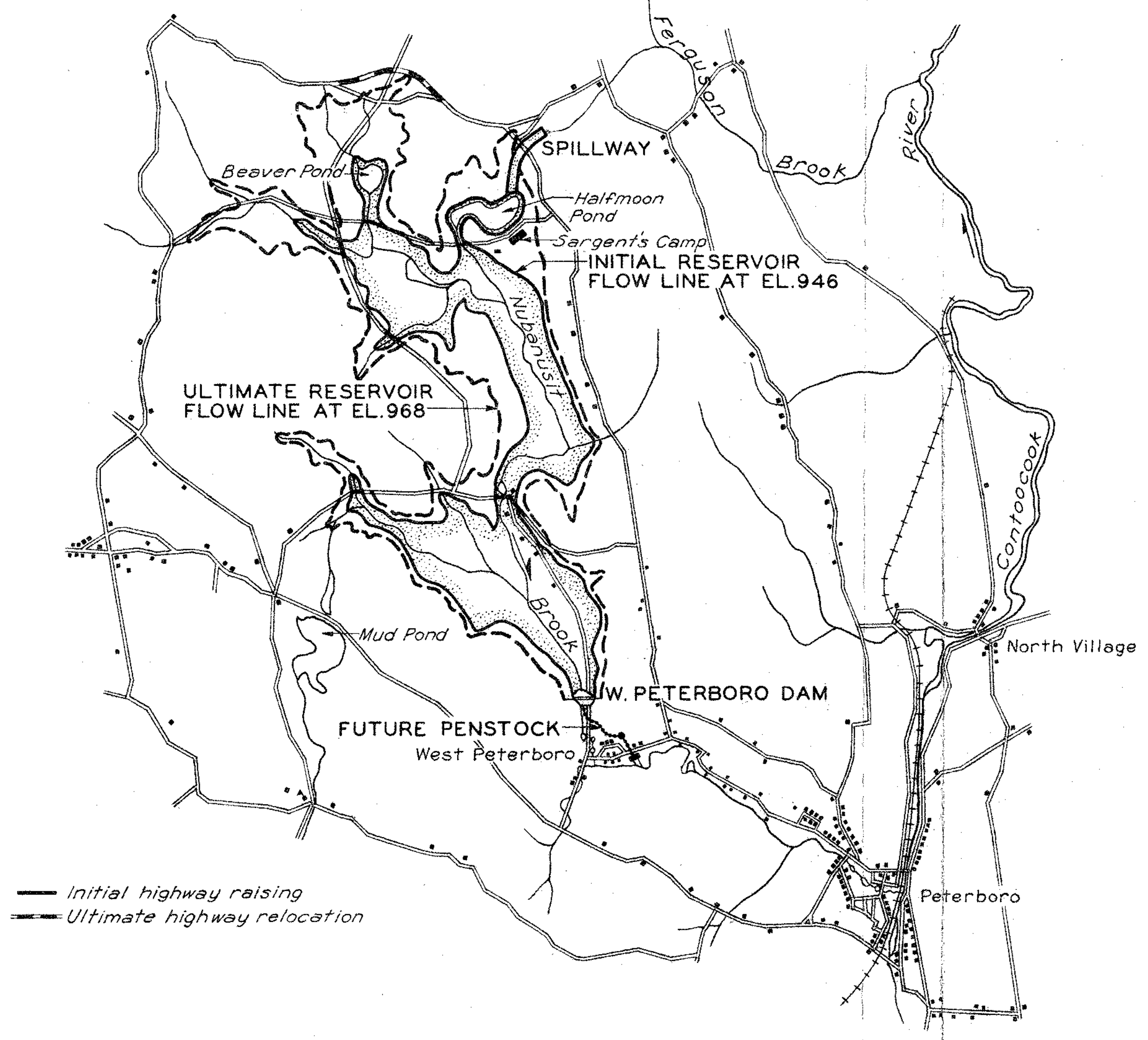
9. Comparison of One-Stage and Two-Stage Developments.- The cost of construction of the reservoir in two stages as outlined above is estimated as $2,213,000. The estimated cost if the project were built to the full height in one stage is $1,700,000. This difference of $513,000 is accounted for by the additional cost necessary for providing a spillway at the lower elevation of the first stage. The saddle available for a spillway requires only a small amount of excavation for one-stage construction to ultimate spillway elevation 968, but for a lower reservoir with spillway elevation 946, as required for flood control only, a deep cut involving 260,000 cubic yards of excavation is necessary. The cost of this cut plus the cost of building a new weir to a higher elevation represents the principal difference in costs of the one-stage and two-stage development. Because of low elevation of rock at the dam site, a spillway at the dam in the initial stage would be less economical than the deep cut at the saddle location.

10. Annual Carrying Charges were computed as follows, assuming the entire cost of the project as Federal investment and construction period as one year:

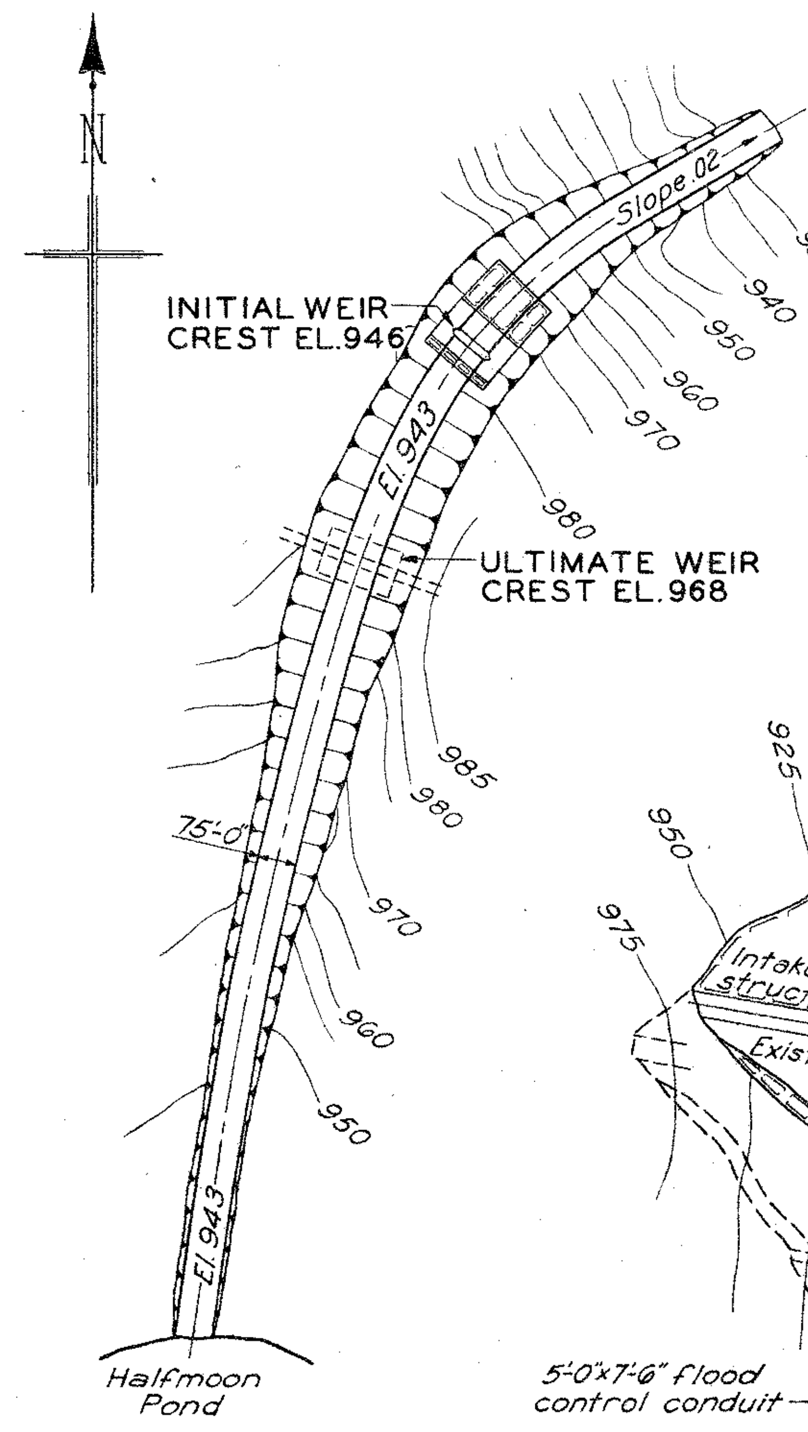
| Item | 1st Stage Flood Control Only | 2nd Stage Flood Control & Conservation |
|---|---|---|
| TOTAL INVESTMENT | | |
| (a) Structures with 50-yr. life | $ 1,255,000 | $ 897,000 |
| (b) Equipment with 25-yr. life | 45,000 | 16,000 |
| (c) Total Investment (all Federal) | $ 1,300,000 | $ 913,000 |
| ANNUAL CHARGES | | |
| Interest on total investment - 3-1/2% | $ 45,500 | $ 31,960 |
| Amortization | | |
| (a) Structures with 50-yr. life - 0.763% | 9,575 | 6,840 |
| (b) Equipment with 25-yr. life - 2.567% | 1,155 | 410 |
| Operation and Maintenance | 4,000 | 1,000 |
| Total Annual Charges | $ 60,230 | $ 40,210 |

WAR DEPARTMENT

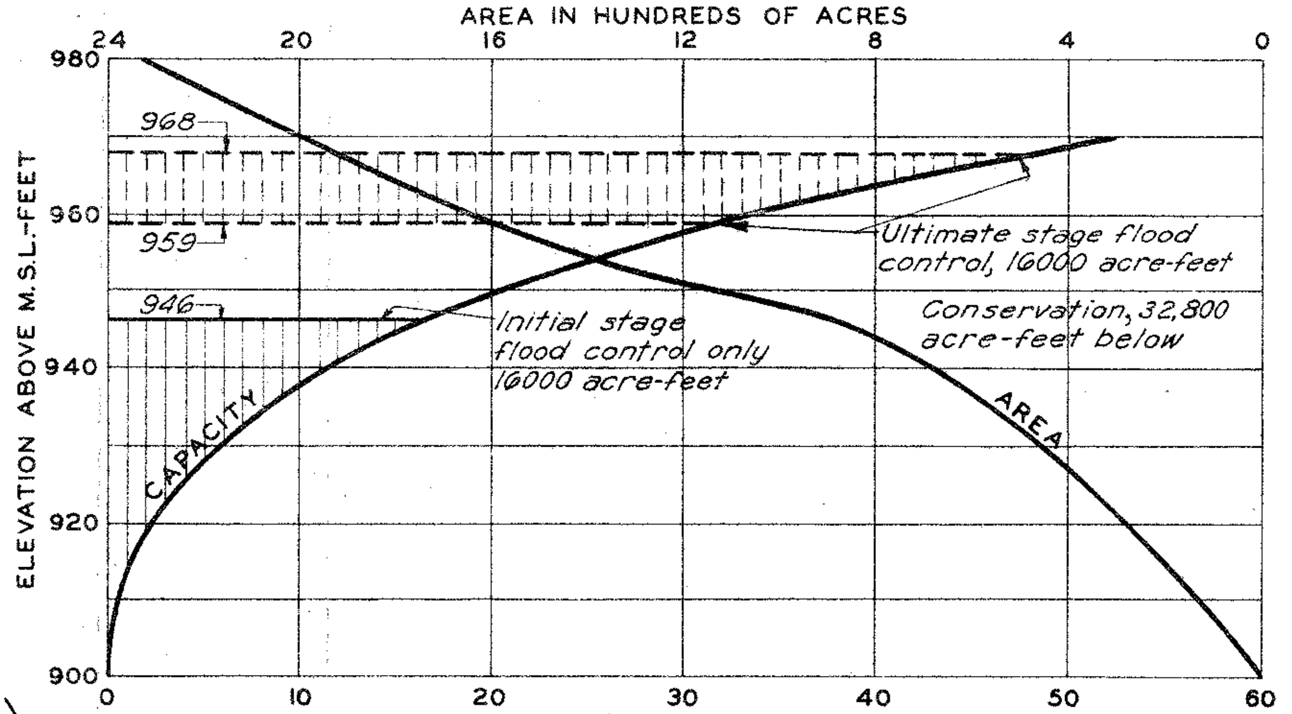
CORPS OF [redacted] ENGINEERS, U. S. ARMY




RESERVOIR

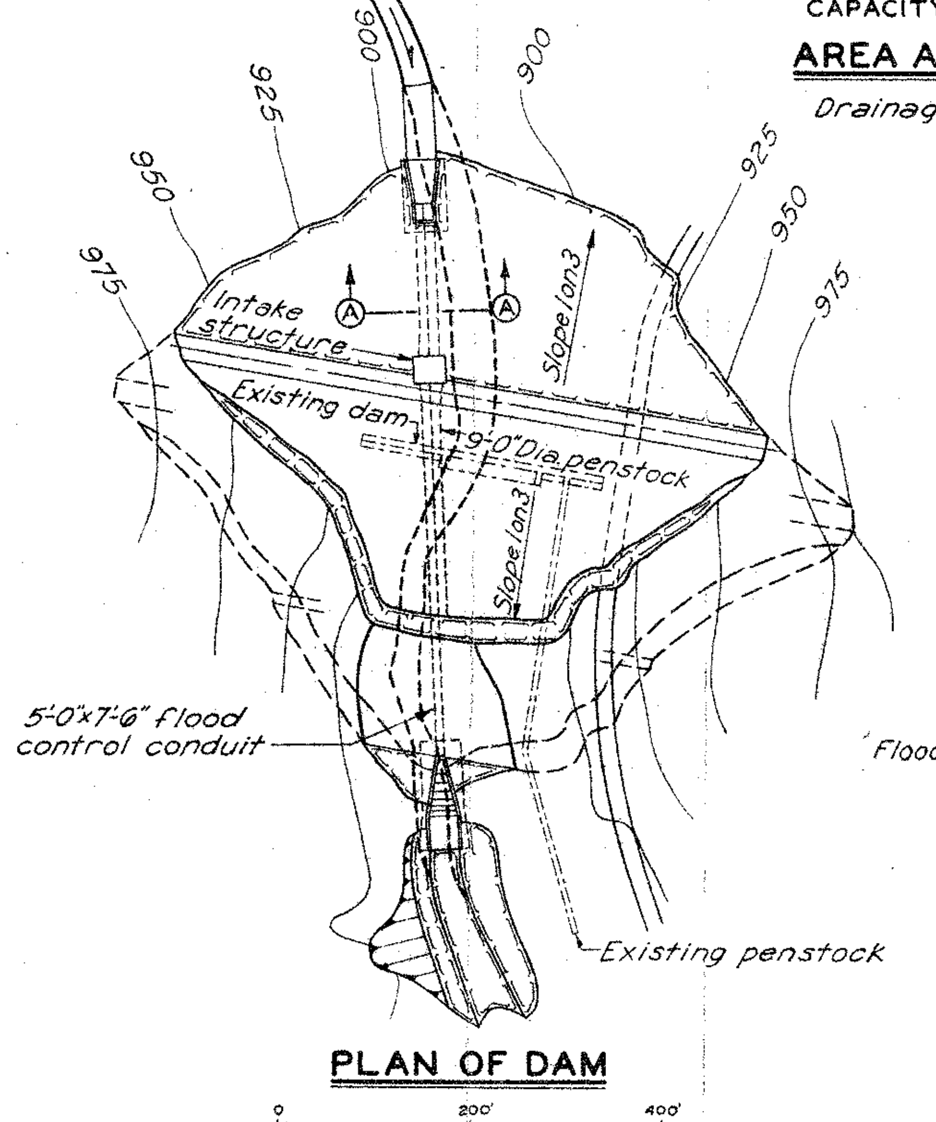



PLAN OF SPILLWAY

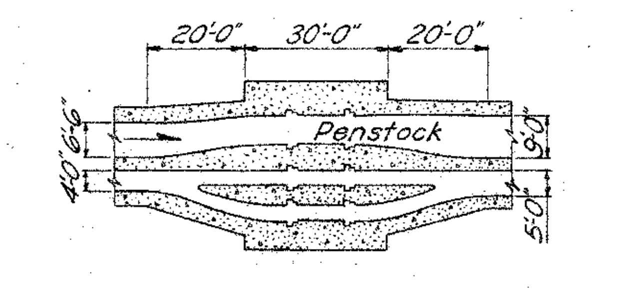



AREA AND CAPACITY CURVES

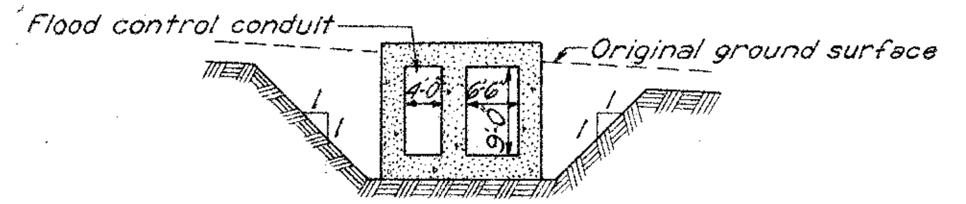
Drainage Area - 44.0 square miles



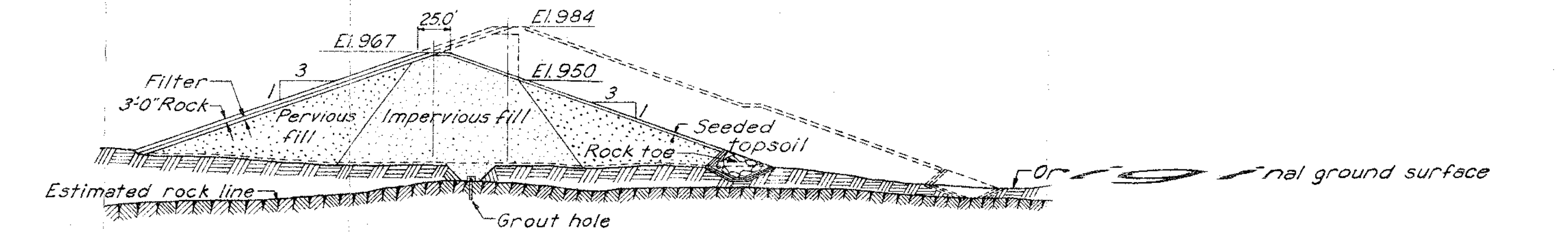

PLAN OF DAM



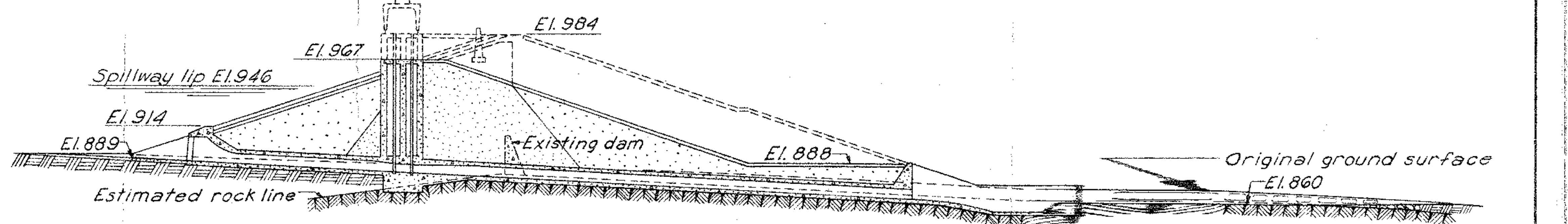

SECTION THRU TRANSITION



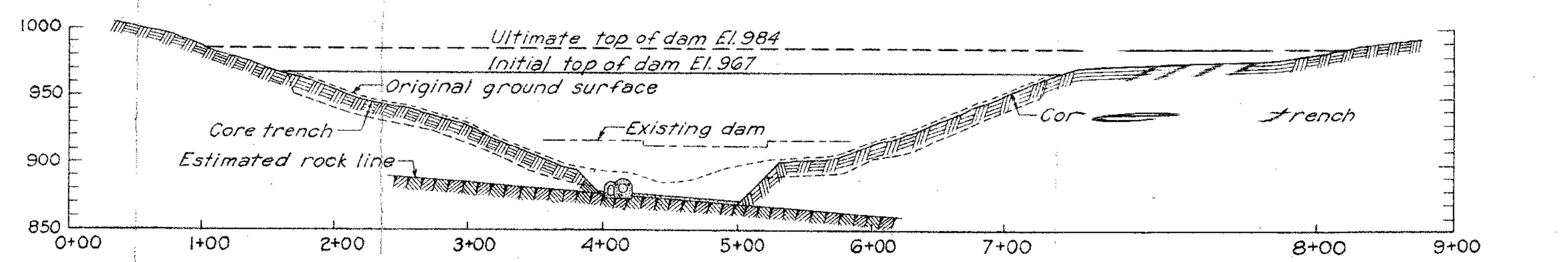

SECTION A-A




TYPICAL EMBANKMENT SECTION




SECTION THRU OUTLET WORKS




SECTION ON ℄ OF DAM

Notes:
Proposed limits of structures for ultimate development are shown as broken lines in all views.

MERRIMAC[redacted]K VALLEY FLOOD CONTROL
WEST P[redacted]TERBORO RESERVOIR
[redacted]UBANUSIT RIVER
SCALE AS SHOWN
U. S. ENGINEER [redacted] OFFICE, BOSTON, MASS.

FILE NO. M100-40/11

PLATE A1

SECTION B

MERRIMACK REPORT DATED APRIL 1, 1940
APPENDIX - SECTION B
DATA FOR ECONOMIC JUSTIFICATION

1. Data Available.- There are unofficial records of damaging floods in the Merrimack Basin as far back as 1785, but there are no statistics on flood damages until 1927. Losses amounting to $2,365,000 were suffered in the flood of November 1927, but the flood damages were not general throughout the basin and the data on losses are not complete enough for use in the economic analysis of flood protection works. The greatest flood of record in the Merrimack Basin occurred in March 1936. Complete statistics for this flood were obtained by means of a comprehensive field survey immediately following the flood period. Stage-loss and frequency relations and average annual flood losses were determined from these data. The second greatest flood of record occurred two years later, in September 1938, and additional statistics were obtained immediately following the flood period by methods similar to those used in 1936. The 1938 data were used to check and modify, where necessary, the stage-loss, frequency, and average annual loss determinations made in 1936. The figures reported herein are based on consideration of all data available, including those of the September 1938 flood.

2. Field Survey Methods.- The statistics on flood losses, both direct and indirect, caused by the floods of March 1936 and September 1938, were obtained immediately following the floods by means of a thorough canvass of individual sufferers throughout the basin. The losses were estimated at the site of the damage and, where possible, in direct conference with the person or persons best qualified to make the estimate. In addition to the estimate of the total loss at each specific location, the increments of loss attributable to selected intervals of stage were also estimated at the site. Elevations for use in referring the damage data to definite control points were obtained by means of high water profile surveys, conducted simultaneously with the damage surveys. The principal reaches for which damage statistics

were summarized, together with the control point for each reach, are listed in the following tabulation:

TABLE B1 - REACHES FOR FLOOD DAMAGE STUDY

| Reach No. | Reach Designation | Limits of Reach (Miles above Newburyport Light) | Type and Location of Control Point |
|---|---|---|---|
| Main Stem, Merrimack River | | | |
| M-1 | Haverhill | 5.0 to 29.0 | Haverhill Bridge, Mile 19.1 |
| M-2 | Lawrence | 29.0 to 36.8 | Essex Dam, Mile 29.0 |
| M-3 | Lower Lowell | 36.8 to 40.6 | Boott Mill Gage, Mile 39.0 |
| M-4 | Upper Lowell | 40.6 to 49.8 | Pawtucket Dam, Mile 40.6 |
| M-5 | Lower Nashua | 49.8 to 54.8 | Cross-section, Mile 51.0 |
| M-6 | Upper Nashua | 54.8 to 62.3 | Cross-section, Mile 55.0 |
| M-7 | Lower Manchester | 62.3 to 73.1 | Granite St.Bridge, Mile 72.0 |
| M-8 | Upper Manchester | 73.1 to 82.9 | Amoskeag Dam, Mile 73.1 |
| M-9 | Garvins Falls | 82.9 to 100.7 | U.S.#4 Bridge, Mile 91.6 |
| M-10 | Franklin Jct. | 100.7 to 118.5 | U.S.G.S. Gage, Mile 114.7 |
| Contoocook River | | | |
| Ck-1 | Penacook | 100.7 to 109.6 | U.S.G.S. Gage, Mile 101.4 |
| Ck-2 | Tyler | 109.6 to 112.4 | Cross-section, Mile 110.0 |
| Ck-3 | Hopkinton | 112.4 to 122.6 | Cross-section, Mile 112.4 |
| Ck-4 | Henniker | 122.6 to 127.2 | Norton Dam, Mile 125.0 |
| Ck-5 | Hillsboro | 127.2 to 135.1 | Hillsboro Mfg.Co.Dam,Mile 133.3 |
| Ck-6 | Antrim | 135.1 to 146.1 | Cross-section, Mile 139.0 |
| Ck-7 | Bennington | 146.1 to 150.7 | Cross-section, Mile 146.7 |
| Ck-8 | Lower Peterboro | 150.7 to 159.0 | Transcript Dam, Mile 158.5 |
| Ck-9 | Upper Peterboro | 159.0 to 162.4 | Noone Dam, Mile 160.3 |
| Ck-10 | E. Jaffrey | 162.4 to 167.6 | Dam at Mile 166.0 |
| Pemigewasset River | | | |
| P-1 | Bristol | 118.5 to 140.8 | Ayers Island Tailrace, Mile 130.9 |
| P-2 | Plymouth | 140.8 to 149.1 | U.S.G.S. Gage, Mile 146.9 |
| Piscataquog River | | | |
| Pq-1 | Goffstown | 71.3 to 87.4 | Cross-section, Mile 86 |

3. Direct Losses.- Estimates of direct losses included all items of physical damage to property such as buildings, equipment, supplies, manufactured goods and records, and all direct expense necessitated by the flood emergency. In the compilation the damage figures were grouped into the following classes:

Industrial. - manufacturing establishments.

Commercial. - trading establishments, wholesale and retail stores and warehouses, banks and professional offices.

Residential. - grounds, buildings, equipment, personal property, furniture and furnishings.

Agricultural. - farming property, crops, and livestock.

Railways. - steam lines, inter-urban electric lines, and bridges.

Highways. - highways, streets, and bridges.

Utilities. - electric power, gas, sewage disposal plants, waterworks, telephone and telegraph.

Public. - damage to property of Federal, State and municipal agencies and cost of emergency relief furnished by them.

Items of loss which will not occur again, such as bridges rebuilt at higher elevations, buildings moved, etc., were eliminated from the statistics. The total direct, recurrable losses in the Merrimack Basin during the floods of March 1936 and September 1938 are summarized on Plates B1 and B2.

4. Indirect Losses.- Estimates of indirect losses included a determination of the value of service or use lost or made necessary by reason of flood conditions. Such losses included the loss of business caused by the cessation of productive industry or commerce both within and without the flooded area, loss of wages to employees, costs of re-routing communications and transportation, and all items of loss or expense, other than physical damage, attributable to the interruption of normal commercial and social processes. Wherever possible, an estimate of indirect losses was obtained from all individuals and agencies reporting direct flood damage. The relation between the direct and indirect losses was computed for all items of loss reported. Using this ratio of direct to indirect loss for each class (i.e., industrial, commercial, etc.) of damage, an indirect damage factor was derived for each reach. The total of direct and indirect losses was then determined by applying the indirect damage factor to the total direct losses for each reach, as shown for the 1936 and 1938 floods on Plates B1 and B2.

5. Stage-Loss Relations.- In the field survey, the amount of loss suffered at high water, the stage at which damage begins, and an estimate

of the loss that would be suffered at several intermediate stages were recorded. From these data a stage-loss relationship was determined for each of the river reaches listed in paragraph 2. For the Merrimack Basin the stage-loss relations were first determined following the flood of March 1936. The additional data on the September 1938 flood were plotted directly on the stage-loss curves previously determined and adjustments made in the stage-damage relations where necessary. In general, few changes were necessary in the Merrimack Basin data except for the Contoocook River, where the 1938 flood exceeded the 1936 flood at several gaging points. The stage-loss relation for the Lower Lowell Reach on the main stem of the Merrimack River, together with the stage-discharge relation for that reach, is shown on Plate B3.

6. Frequency Relations.- Discharge-frequency relations were computed by applying simple frequency formulae to the actual flood records at the following localities:

| Locality | Miles above Mouth of Merrimack R. | Net Drainage Area* | Length of Record |
|---|---|---|---|
| Merrimack at Lawrence, Mass. | 29 | 4201 | 90 |
| Merrimack at Franklin Jct. | 115 | 1036 | 35 |
| Pemigewasset at Plymouth | 147 | 622 | 53 |
| Contoocook at Penacook | 101 | 766 | 11 |
| Souhegan at Merrimack | 63 | 171 | 29 |

Data on historic floods were taken into account in the computations for the above stations. Frequency relations for intermediate reaches were interpolated in accordance with the method illustrated below for the Lower Lowell Reach.

*The net drainage areas used in these frequency studies are the total drainage areas above each point minus the areas which are practically controlled and which, therefore, do not influence flood flows in proportion to their drainage area, (e.g., Lake Winnipesaukee).

$q$ = discharge per square mile at control point in intermediate reach (in this case, Lower Lowell)

$q_1$ = discharge per square mile at Lawrence (below Lower Lowell)

$q_2$ = discharge per square mile at Franklin Junction (above Lower Lowell)

$D_1$ = net drainage area at Lawrence (4201 sq.mi.)

$D_2$ = net drainage area at Franklin Junction (1036 sq.mi.)

$D$ = net drainage area at control point of intermediate reach (3659 sq.mi.)

$$q = \frac{(D_1 - D)}{(D_1 - D_2)} (q_2 - q_1) + q_1 \quad \text{or} \quad q = K (q_2 - q_1) + q_1$$

for this point, $K = \frac{4201 - 3659}{4201 - 1036} = 0.17$

then, $q = 0.17 (q_2 - q_1) + q_1$ , as computed in the table below:

TABLE B2 - COMPUTATION FOR DISCHARGE-FREQUENCY RELATIONSHIP AT LOWELL, MASS.

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|
| Probability of Occurrence in Any One Year | Franklin Junction 24-Hr. Discharge c.f.s. | Lawrence 24-Hr. Discharge c.f.s. | Franklin Junction Discharge-c.f.s. Per Sq.Mi. $q_2$ | Lawrence Discharge-c.f.s. Per Sq.Mi. $q_1$ | Col.(4) Minus Col.(5) $q_2-q_1$ | Col.(6) x 0.17 $K(q_2-q_1)$ | Lower Lowell Discharge-c.f.s. Per Sq.Mi. Col.(5) + Col.(7) | Lower Lowell 24-Hr. Discharge c.f.s. |
| 1.0 | 19,500 | 36,500 | 18.8 | 8.7 | 10.1 | 1.7 | 10.4 | 38,100 |
| 0.5 | 25,200 | 45,000 | 24.3 | 10.7 | 13.6 | 2.3 | 13.0 | 47,700 |
| 0.1 | 39,900 | 68,000 | 38.5 | 16.2 | 22.3 | 3.8 | 20.0 | 73,200 |
| 0.05 | 47,400 | 81,000 | 45.8 | 19.3 | 26.5 | 4.5 | 23.8 | 87,200 |
| 0.01 | 68,800 | 117,000 | 66.4 | 27.8 | 38.6 | 6.6 | 34.4 | 125,900 |
| 0.005 | 79,900 | 136,000 | 77.0 | 32.4 | 44.6 | 7.6 | 40.0 | 146,500 |
| 0.001 | 108,800 | 185,500 | 105.0 | 44.1 | 60.9 | 10.4 | 54.5 | 199,500 |

The relationship between the momentary peak and 24-hour discharge was computed for all flows for which both values were known. These factors varied from about 10 per cent to 15 per cent; in the Lower Lowell Reach this "peaking" factor was 11.1 per cent. The computed frequency curves for the Lower Lowell Reach are shown on Plate B4.

7. <u>Determination of Average Annual Losses</u>.- The average annual direct loss was determined by plotting a damage-frequency curve for each reach. The amounts of damage from zero to the losses expected from the largest probable flood were plotted against the computed frequency of the flood stages necessary to cause those damages. The values were plotted as a closed damage-frequency curve over the entire range of probability from zero to 100 per cent chance of occurrence. The average annual loss was determined from this curve by computing the mean ordinate. (Since "probability of occurrence in any one year" was used for the frequency scale, the mean ordinate or average annual loss is equal to the area under the curve.) For the purposes of the economic study, the "largest probable flood" was taken as 15 per cent larger than the 1936 flood, the greatest of record. The frequency of the 1936 flood was computed as 1 per cent chance in the upper Merrimack Basin and 0.3 per cent chance in the lower reaches. Since the frequency period of the largest probable flood is difficult, if not impossible, to predict accurately, and to allow for the possibility of the largest probable flood occurring within the life of the flood control works under consideration, the natural damage frequency curve was distorted by assigning a frequency of 0.01 (1 per cent chance) to the damages of the largest probable flood. The damage-frequency curve for the Lower Lowell Reach is shown on Plate B5.

8. <u>Benefits of Reservoir Control.</u>- Average annual benefits to be credited to reservoirs were determined from modified damage-frequency curves as shown on Plate B5. First step in the procedure was to route four floods downstream through all reaches to determine the stage and discharge reductions in each reach for several degrees of reservoir control, covering the range of control expected to be analyzed. The natural and modified discharges for the four floods for the Lower Lowell Reach are as follows:

| Size of Flood Routed | Uncontrolled Discharge (Curve 1) | Reduced Discharges for: Control #1 (Curve 2) | Control #2 (Curve 3) | Control #3 (Curve 4) | Control #4 (Curve 5) |
|---|---|---|---|---|---|
| 1936 + 15% | 191,000 | 182,000 | 173,000 | 142,000 | 133,000 |
| 1936 | 166,000 | 140,000 | 132,500 | 107,500 | 101,000 |
| 2/3 of 1936 | 110,700 | 98,000 | 92,500 | 77,000 | 71,000 |
| 1/3 of 1936 | 55,300 | 55,000 | 52,500 | 47,000 | 44,000 |

The amounts of damage corresponding to the foregoing reduced discharges were plotted against the same frequency values applicable to the uncontrolled discharges. The modified curves for each degree of control were then drawn. The benefit for each degree of control is the difference in area between the natural and modified curves. To obtain the benefit for the distorted zone of the curve (Section D on Plate B5), the same percentage of damage reduction resulting for the non-distorted portion of the curve was applied to the distorted section. To obtain a "working curve" for determination of benefits of any amount of reservoir control, the benefits for the four degrees of control shown on Plate B5 were plotted against stage and discharge reductions for the 1936 flood as an "index flood," as shown on Plate B6. It was then necessary to route only the 1936 flood for any specific reservoir or system and determine the "index" reduction for each reach. The benefits were then obtained from the working curve (Plate B6). The benefits determined for the reservoirs contemplated under the existing project (Franklin Falls, Blackwater and Hopkinton-Everett) and the additional benefits for the proposed West Peterboro Reservoir are summarized in the following table:

TABLE B3 - SUMMARY OF RESERVOIR BENEFITS

| Reaches | Uncontrolled 1936 Flood | | Un-controlled Average Annual Damage | 1936 Flood Reduced by B-F-H | | Annual Benefits of B-F-H | Additional Benefits W.Peterboro Reservoir |
|---|---|---|---|---|---|---|---|
| | Stage (MSL) | Discharge (c.f.s.) | | Stage (MSL) | Discharge (c.f.s.) | | |
| Main Stem - Merrimack River | | | | | | | |
| Haverhill | 28.2 | 177,000 | $ 295,000 | 23.0 | 129,700 | $ 163,000 | $ 3,000 |
| Lawrence | 53.1 | 174,000 | 65,000 | 50.1 | 122,800 | 28,000 | 1,000 |
| Lower Lowell | 76.0 | 166,000 | 173,000 | 68.8 | 111,000 | 115,000 | 2,000 |
| Upper Lowell | 106.0 | 166,000 | 74,000 | 99.7 | 111,000 | 41,000 | 1,000 |
| Lower Nashua | 123.5 | 165,000 | 46,000 | 110.2 | 103,500 | 42,000 | 1,000 |
| Upper Nashua | 128.0 | 155,000 | 35,000 | 114.9 | 93,500 | 33,000 | - |
| Lower Manchester | 151.0 | 144,000 | 549,000 | 139.6 | 78,500 | 449,000 | 5,000 |
| Upper Manchester | 188.3 | 144,000 | 89,000 | 183.3 | 78,500 | 77,000 | 2,000 |
| Garvins Falls | 243.5 | 122,000 | 80,000 | 234.7 | 49,400 | 78,000 | 1,000 |
| Franklin Jct. | 285.8 | 83,000 | 14,000 | 274.1 | 44,600 | 13,000 | - |
| Contoocook River | | | | | | | |
| Penacook | 294.0 | 46,800 | 14,800 | 287.6 | 17,400 | 13,800 | 1,000 |
| Tyler | 368.0 | 38,300 | 200 | 356.6 | 14,000 | 200 | - |
| Hopkinton | 368.5 | 27,700 | 3,000 | 356.8 | 9,400 | 3,000 | - |
| Henniker | 410.9 | 24,800 | 11,000 | - | - | - | 3,000 |
| Hillsboro | 585.8 | 24,000 | 6,000 | - | - | - | 2,000 |
| Antrim | 602.5 | 15,500 | 2,000 | - | - | - | 1,000 |
| Bennington | 673.0 | 13,600 | 25,000 | - | - | - | 14,000 |
| Lower Peterboro | 724.5 | 9,000 | 27,000 | - | - | - | 21,000 |
| Upper Peterboro | 770.9 | 5,500 | 16,000 | - | - | - | - |
| East Jaffrey | 982.4 | 2,600 | 17,000 | - | - | - | - |
| Pemigewasset River | | | | | | | |
| Bristol | 393.2 | 71,400 | 10,000 | - | - | - | - |
| Plymouth | 486.0 | 65,400 | 48,000 | - | - | - | - |
| Piscataquog River | 332.0 | 19,900 | 10,000 | 327.0 | 13,600 | 8,000 | - |
| TOTAL | - | - | $1,610,000 | - | - | $1,064,000 | $58,000 |

9. Benefits of Local Protection Measures.- The average annual benefits of local flood protective works were determined by methods similar to those for reservoir control. Separate damage-frequency relations were established for each local area analyzed. For channel improvements the benefit was computed as the difference between natural and modified relations exactly as for reservoir control. For dikes or walls the benefit was taken as equal to the average annual loss for the entire range of stage up to the maximum stage for which the dikes or walls were designed.

10. Restoration of Depressed Property Values.- In the study of depreciation of property value in areas subject to flooding in the Merrimack Basin, statistics on the assessed property valuation on record in assessors' offices for the years 1935 and 1939 were obtained. These dates were selected as representing the probable extreme range of difference in property values attributable to flood conditions since they are the years immediately preceding and following the three-year period in which the two greatest floods of record occurred in this basin. Comparison of the assessed valuation statistics revealed no definite depreciation during that period. Studies of the market values of the property, however, indicated that property in urban flood zones had depreciated from 10 to 50 per cent. It was the opinion of many real estate brokers, bankers, and business men in the cities concerned that an average depreciation of 15 per cent for industrial properties and 30 per cent for residential properties was a conservative estimate of the amount of depreciation attributable to the existence of a flood threat to these properties. The average annual value of property depreciation was computed for the urban areas of the basin using the depreciation rates mentioned above and assuming that the depreciation would be recovered under natural conditions in 20 years. It was also assumed that property flooded more frequently than once in 20 years was permanently depressed in value, and, therefore, that no restoration of value could occur either by natural means or as a result of flood control measures. The average annual benefit of restoring depreciated values was taken as 5 per cent of the total restored value, this amount representing the earning power of the property. The computation of the benefits was similar to that used for flood damages. The capitalized value of average annual flood damage in the area concerned was subtracted from the amount of depreciation to avoid duplication of benefits. The total amount of benefit possible if all property depreciation in urban flood zones in the Merrimack Basin were restored was computed as about $60,000 annually. Since this amount is only a small percentage of the average annual value of direct and indirect flood damages, and since the

computation of the annual value of restored depreciation is necessarily dependent on a number of debatable assumptions, no credit was claimed for restoration of property values in this basin.

11. Enhancement in Value of Areas Protected.- In addition to investigation of the extent of depreciation of property values in urban flood zones, the possibility that flood control measures might result in enhancement of value of undeveloped or partially developed property has been considered. In general, the actual area subject to flooding in this basin is not large. The flood problem arises principally from the fact that severe flood losses are possible within comparatively small areas in the cities and towns concentrated on the stream banks. The amount of agricultural land made available by reduction of flood stages is not sufficiently large to result in appreciable general benefit. Flood control measures have their principal benefit in the prevention of direct and indirect flood damage. A few urban zones are benefitted in such a manner that enhancement of property values may result, but the economic future of the cities in the basin is too uncertain to permit a dependable estimate of the value of such enhancement at this time.

MERRIMACK BASIN - FLOOD DAMAGES, MARCH 1936

| River Reach | Total Direct Damage 1936 | % of Direct Damage in Each Class | | | | | | | | Indirect Damage Factor | Total Direct and Indirect Damage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Industrial | Commercial | Residential | Agricultural | Railroads | Highways | Utility | Public | | |
| Haverhill | $ 5,258,000 | 35.4 | 21.6 | 15.7 | 1.6 | 1.3 | 2.0 | 5.8 | 16.6 | 2.0 | $10,516,000 |
| Lawrence | 590,000 | 6.7 | 15.6 | 23.3 | 2.0 | 0 | 19.0 | 5.1 | 28.3 | 1.6 | 944,000 |
| Low.Lowell | 3,042,000 | 36.4 | 17.1 | 27.4 | 0 | 0 | 4.5 | 2.4 | 12.2 | 1.9 | 5,779,800 |
| Upp.Lowell | 840,000 | 18.2 | 17.7 | 18.1 | 6.6 | 17.7 | 0.5 | 2.2 | 19.0 | 1.7 | 1,428,000 |
| Lower Nashua | 995,000 | 34.8 | 12.1 | 29.4 | 1.0 | 8.7 | 0.8 | 4.2 | 9.0 | 2.0 | 1,990,000 |
| Upper Nashua | 638,000 | 30.7 | 1.6 | 22.9 | 7.9 | 16.1 | 1.3 | 11.9 | 7.6 | 1.9 | 1,212,200 |
| Low.Manchester | 1,956,000 | 55.0 | 6.2 | 12.0 | 2.1 | 8.7 | 2.6 | 2.6 | 10.8 | 1.9 | 3,716,400 |
| Upp.Manchester | 754,000 | 9.4 | 4.1 | 17.4 | 1.4 | 58.1 | 2.3 | 2.1 | 5.2 | 1.6 | 1,206,400 |
| Garvins Falls | 792,000 | 2.9 | 11.3 | 17.6 | 2.8 | 53.7 | 1.0 | 9.0 | 1.7 | 1.6 | 1,267,200 |
| Franklin Jct. | 217,000 | 12.5 | 4.6 | 22.8 | 29.8 | 14.3 | 3.8 | 2.1 | 10.1 | 1.6 | 347,200 |
| Sub-Total, Merrimack R. | $15,082,000 | 32.5 | 15.1 | 19.5 | 2.3 | 9.8 | 3.0 | 4.6 | 13.2 | 1.88 | $28,407,200 |
| Penacook | 113,000 | 39.5 | 1.9 | 23.2 | 1.6 | 0 | 11.6 | 19.8 | 2.4 | 2.0 | 226,000 |
| Tyler | 3,800 | 0 | 0 | 44.8 | 36.2 | 0 | 19.0 | 0 | 0 | 1.2 | 4,600 |
| Hopkinton | 59,700 | 24.7 | 12.3 | 24.0 | 5.2 | 16.2 | 3.6 | 2.9 | 11.1 | 1.7 | 101,500 |
| Henniker | 31,300 | 31.9 | 0.7 | 1.7 | 6.9 | 9.4 | 37.8 | 9.0 | 2.6 | 1.7 | 53,200 |
| Hillsboro | 66,400 | 17.0 | 0.3 | 2.4 | 1.0 | 71.8 | 3.8 | 3.5 | 0.2 | 1.7 | 112,900 |
| Antrim | 8,900 | 0 | 0 | 5.6 | 2.2 | 38.4 | 53.8 | 0 | 0 | 1.2 | 10,700 |
| Bennington | 15,600 | 25.6 | 0 | 0 | 7.1 | 0 | 3.2 | 57.7 | 6.4 | 2.0 | 31,200 |
| Low.Peterboro | 90,400 | 0 | 13.7 | 10.3 | 0 | 38.9 | 15.9 | 6.9 | 14.3 | 1.6 | 144,600 |
| Upp.Peterboro | 58,100 | 90.4 | 0 | 0 | 0 | 0 | 9.6 | 0 | 0 | 2.0 | 116,200 |
| East Jaffrey | 13,700 | 22.0 | 0 | 0.7 | 0 | 12.5 | 43.4 | 0.3 | 21.1 | 1.7 | 23,300 |
| Sub-Total, Contoocook R. | $ 460,900 | 30.4 | 4.8 | 11.8 | 2.3 | 21.8 | 13.3 | 9.7 | 5.9 | 1.79 | $ 824,200 |
| Bristol | 100,700 | 0 | 0 | 10.0 | 25.6 | 42.8 | 9.4 | 7.8 | 4.4 | 1.5 | 151,100 |
| Plymouth | 300,600 | 3.6 | 20.1 | 20.2 | 35.8 | 9.5 | 2.3 | 4.9 | 3.6 | 1.6 | 481,000 |
| Sub-Total, Pemigewasset | $ 401,300 | 2.7 | 15.1 | 17.6 | 33.2 | 17.9 | 4.1 | 5.6 | 3.8 | 1.57 | $ 632,100 |
| Sub-Total, Piscataquog | $ 87,800 | 17.9 | 18.3 | 13.8 | 3.4 | 3.9 | 24.8 | 0.8 | 17.1 | 1.80 | $ 158,000 |
| Total, Above Reaches and Tributaries | $16,032,000 | 31.6 | 14.8 | 19.2 | 3.1 | 10.3 | 3.5 | 4.7 | 12.8 | 1.87 | $30,021,500 |
| Total, All Other Tributaries | $ 3,568,000 | 35.6 | 10.4 | 9.6 | 4.3 | 4.2 | 26.9 | 4.2 | 4.8 | 1.40 | $ 4,978,500 |
| Grand Total, Merrimack Basin | $19,600,000 | 32.3 | 14.0 | 17.5 | 3.3 | 9.3 | 7.7 | 4.6 | 11.3 | 1.79 | $35,000,000 |

PLATE B1

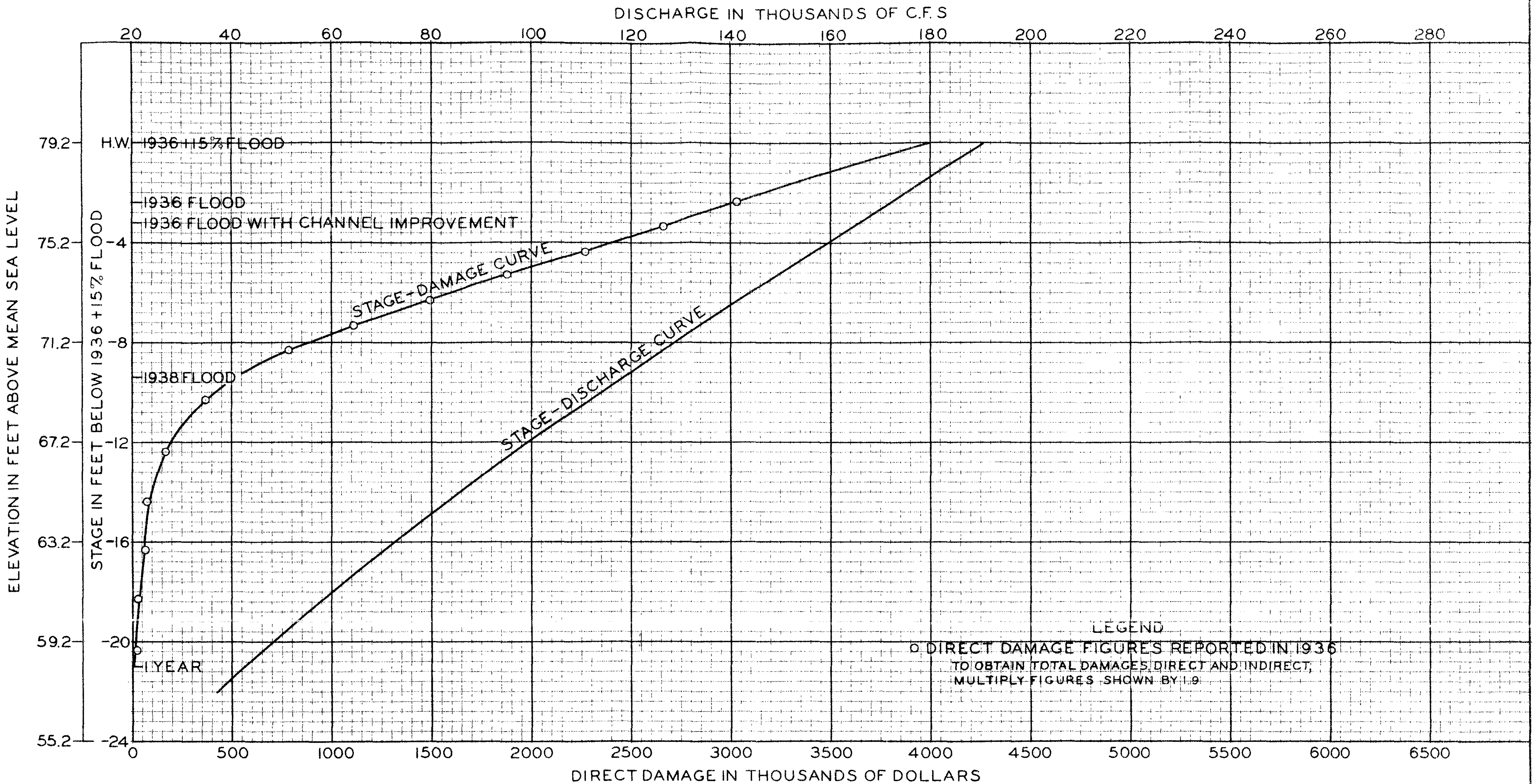
MERRIMACK BASIN - FLOOD DAMAGES - SEPTEMBER 1938

| River Reach | Total Direct Damage 1938 | % of Direct Damage in Each Class | | | | | | | | In-direct Damage Factor | Total Direct and Indirect Damage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Indus-trial | Commer-cial | Resi-dential | Agri-cultural | Rail-roads | High-ways | Utility | Public | | |
| Haverhill | $ 81,000 | 25.5 | 53.2 | 4.9 | 1.5 | 3.4 | 9.2 | 1.2 | 1.1 | 2.0 | $ 162,000 |
| Lawrence | 7,200 | 1.4 | 20.6 | 62.8 | 1.4 | 0 | 12.4 | 1.4 | 0 | 1.6 | 11,500 |
| Lower Lowell | 83,900 | 3.0 | 91.2 | 4.9 | 0 | 0 | 0 | 0.6 | 0.3 | 1.9 | 159,400 |
| Upper Lowell | 92,100 | 18.3 | 20.2 | 11.4 | 5.3 | 29.3 | 0 | 0.1 | 15.3 | 1.7 | 156,600 |
| Lower Nashua | 44,100 | 35.6 | 1.4 | 10.3 | 0 | 24.4 | 23.8 | 0 | 4.5 | 2.0 | 88,200 |
| Upper Nashua | 44,700 | 6.6 | 0 | 12.4 | 44.7 | 36.2 | 0.1 | 0 | 0 | 1.9 | 84,900 |
| Low.Manchester | 79,200 | 25.1 | 10.4 | 7.8 | 0.9 | 10.2 | 44.6 | 0 | 0 | 1.9 | 150,500 |
| Upp.Manchester | 154,900 | 18.1 | 0.5 | 7.0 | 0.8 | 69.7 | 3.6 | 0.3 | 0 | 1.6 | 247,800 |
| Garvins Falls | 205,000 | 1.0 | 15.5 | 7.9 | 4.6 | 36.8 | 22.3 | 0.8 | 11.1 | 1.6 | 328,000 |
| Franklin Jct. | 13,000 | 2.3 | 1.5 | 4.2 | 58.5 | 17.5 | 0 | 0 | 16.0 | 1.6 | 20,800 |
| Sub-Total, Merrimack R. | $ 805,100 | 13.5 | 22.6 | 8.3 | 5.6 | 31.2 | 13.1 | 0.5 | 5.2 | 1.75 | $1,409,700 |
| Penacook | $ 24,300 | 58.9 | 0.3 | 26.8 | 12.4 | 0 | 0 | 1.6 | 0 | 2.0 | $ 48,600 |
| Tyler | 7,200 | 49.5 | 0 | 4.2 | 26.3 | 0 | 0 | 20.0 | 0 | 1.2 | 8,600 |
| Hopkinton | 92,200 | 13.1 | 1.3 | 1.2 | 8.1 | 48.8 | 27.3 | 0.2 | 0 | 1.7 | 156,700 |
| Henniker | 192,200 | 7.9 | 3.2 | 3.6 | 0.5 | 36.4 | 47.6 | 0 | 0.8 | 1.7 | 326,700 |
| Hillsboro | 140,300 | 31.8 | 0.2 | 2.7 | 0.2 | 35.6 | 25.0 | 4.5 | 0 | 1.7 | 238,500 |
| Antrim | 58,200 | 1.4 | 3.1 | 1.1 | 11.1 | 71.9 | 11.1 | 0.1 | 0.2 | 1.2 | 69,800 |
| Bennington | 272,900 | 82.8 | 0 | 0.3 | 0 | 9.2 | 7.5 | 0.2 | 0 | 2.0 | 545,800 |
| Low.Peterboro | 275,200 | 0.1 | 21.6 | 15.0 | 0.7 | 18.5 | 43.6 | 0 | 0.5 | 1.6 | 440,300 |
| Upp.Peterboro | 60,700 | 77.3 | 8.4 | 11.1 | 0 | 0 | 0 | 0 | 3.2 | 2.0 | 121,400 |
| East Jaffrey | 93,600 | 17.5 | 1.3 | 1.1 | 0 | 53.4 | 0 | 0 | 26.7 | 1.7 | 159,100 |
| Sub-Total, Contoocook R. | $1,216,800 | 31.3 | 6.2 | 5.7 | 1.8 | 27.2 | 24.6 | 0.7 | 2.5 | 1.74 | $2,115,500 |
| Bristol | $ 89,500 | 8.8 | 0 | 0.4 | 2.7 | 5.8 | 82.0 | 0.3 | 0 | 1.5 | $ 134,300 |
| Plymouth | 69,900 | 2.7 | 0.5 | 3.9 | 4.4 | 31.1 | 57.4 | 0 | 0 | 1.6 | 111,800 |
| Sub-Total, Pemigewasset | $ 159,400 | 6.1 | 0.2 | 2.0 | 3.4 | 16.9 | 71.2 | 0.2 | 0 | 1.54 | $ 246,100 |
| Sub-Total, Piscataquog | $ 98,700 | 0 | 7.8 | 25.0 | 9.6 | 0 | 52.2 | 1.3 | 4.1 | 1.80 | $ 177,700 |
| Total, Above Reaches and Tributaries | $2,280,000 | 21.9 | 11.6 | 7.2 | 3.6 | 26.8 | 25.0 | 0.6 | 3.3 | 1.73 | $3,949,000 |
| Total, All Other Tributaries | $1,370,000 | 8.5 | 5.9 | 5.1 | 6.8 | 20.4 | 46.5 | 5.7 | 1.1 | 1.50 | $2,051,000 |
| Grand Total, Merrimack Basin | $3,650,000 | 16.9 | 9.5 | 6.4 | 4.8 | 24.4 | 33.0 | 2.5 | 2.5 | 1.64 | $6,000,000 |

PLATE B2

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY




*Note:*

*The Stage-Discharge curve shown is not the rating curve for any specific location in the Lower Lowell Reach. It represents a stage-discharge relation applicable throughout the reach for use in the computation of annual flood losses and benefits.*

*The curve is based on observed stage-discharge relations at the Boott Mill gage in Lowell, with adjustment made for the flow by-passed through the canals.*

MERRIMACK VALLEY FLOOD CONTROL

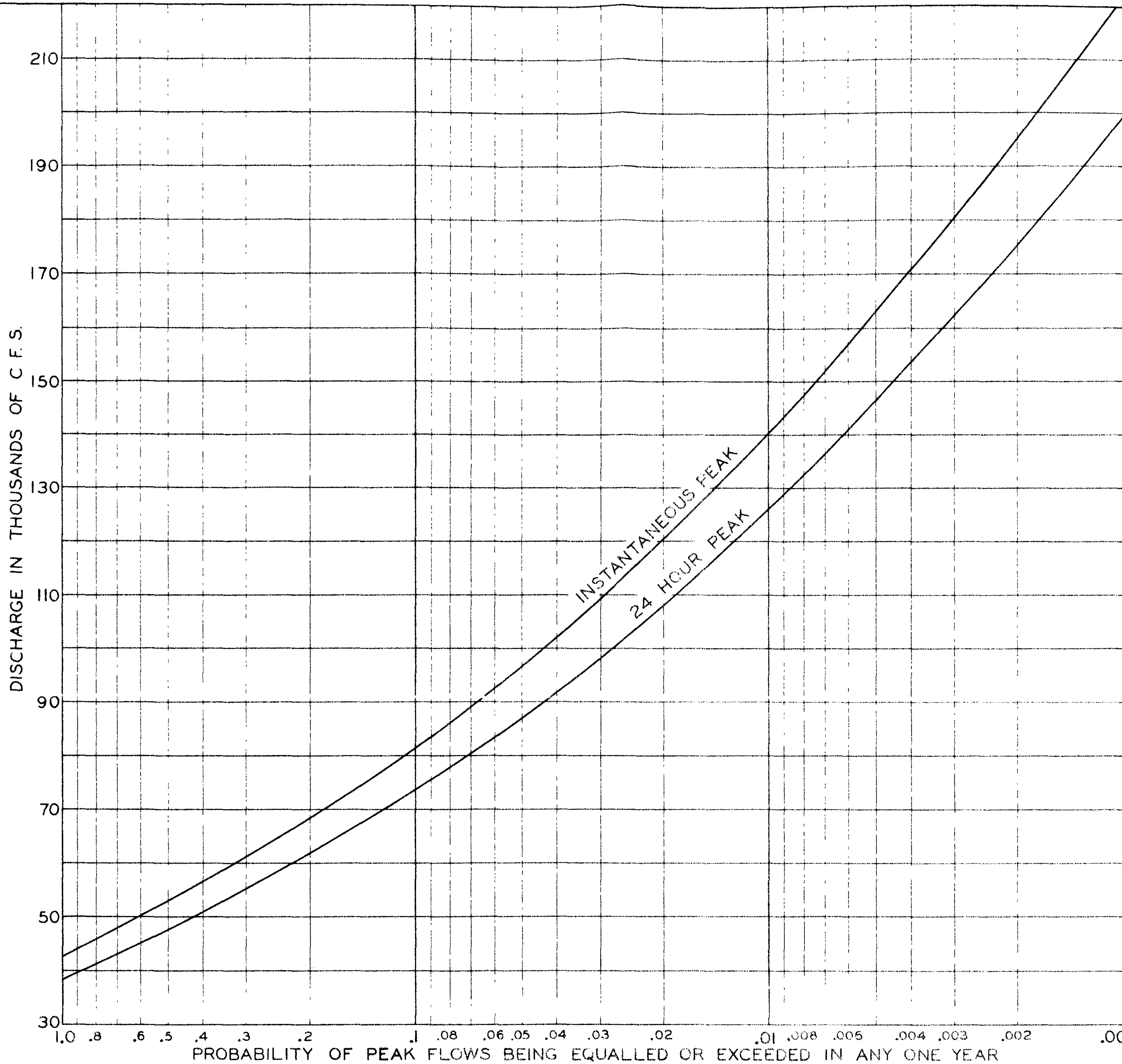
**STAGE DISCHARGE AND STAGE DAMAGE CURVES**

MERRIMACK RIVER-LOWER LOWELL REACH M3

U.S. ENGINEER OFFICE BOSTON, MASS.

APRIL, 1940 FILE NO. M100-40/23

PLATE 83




*Note:*

*The 24-hour peak relation was interpolated between the computed 24-hour peak frequency curves for Lawrence and Franklin on the basis of net drainage area proportions.*

*The instantaneous peak relation was determined by increasing the 24-hour values by 11.1%. This factor was interpolated between known relations of peak to 24-hour discharge at Lawrence and Garvin's Falls.*

*To express the probability scale as "percent chance", multiply the values shown by 100.*

MERRIMACK VALLEY FLOOD CONTROL

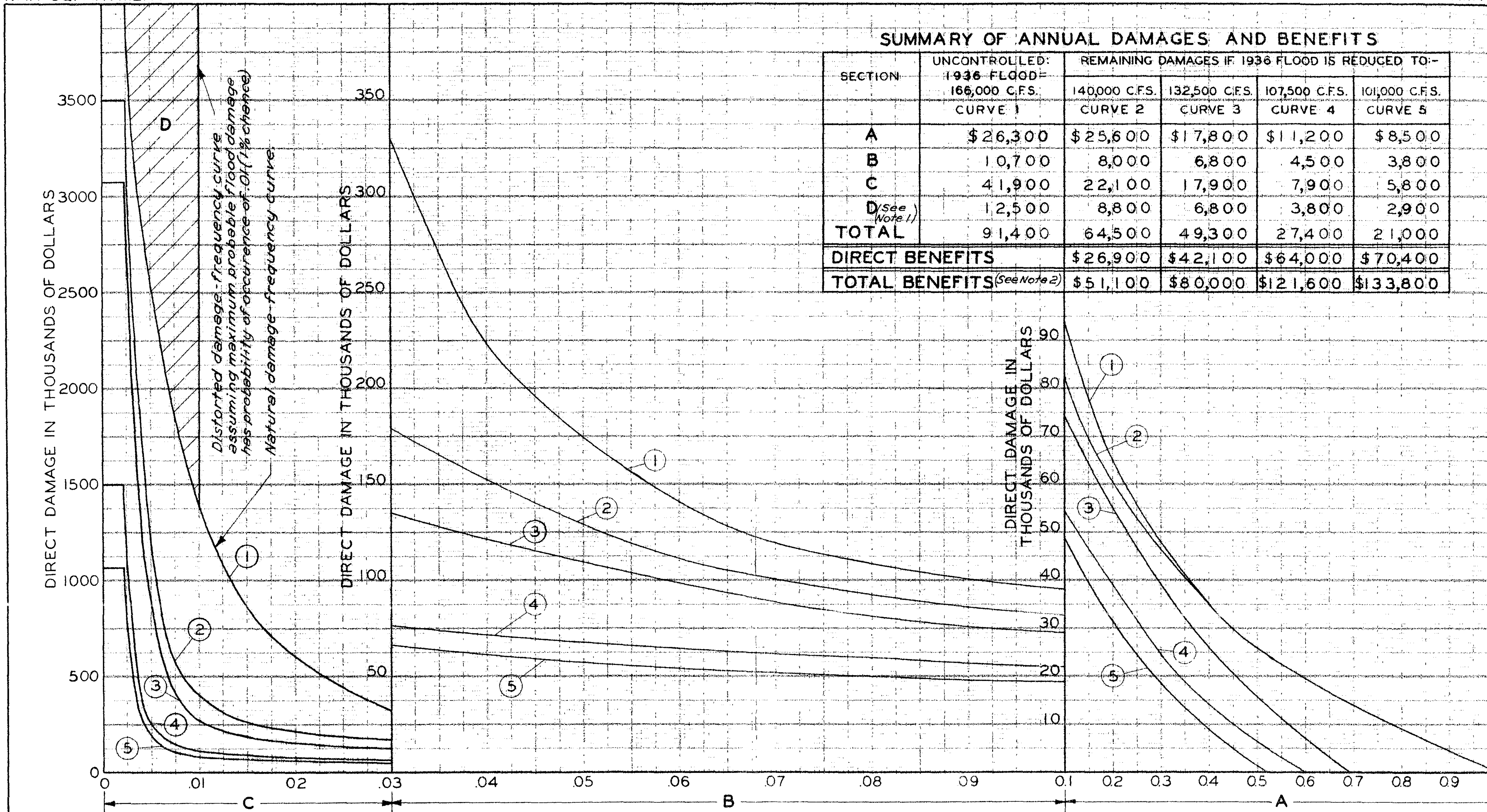
**DISCHARGE-FREQUENCY CURVES**

UPPER AND LOWER LOWELL REACHES
MERRIMACK RIVER

U.S. ENGINEER OFFICE, BOSTON, MASS.
APRIL, 1940 FILE NO M100-40/24

## SUMMARY OF ANNUAL DAMAGES AND BENEFITS

| SECTION | UNCONTROLLED: 1936 FLOOD= 166,000 C.F.S. CURVE 1 | REMAINING DAMAGES IF 1936 FLOOD IS REDUCED TO:- 140,000 C.F.S. CURVE 2 | 132,500 C.F.S. CURVE 3 | 107,500 C.F.S. CURVE 4 | 101,000 C.F.S. CURVE 5 |
|---|---|---|---|---|---|
| A | $26,300 | $25,600 | $17,800 | $11,200 | $8,500 |
| B | 10,700 | 8,000 | 6,800 | 4,500 | 3,800 |
| C | 41,900 | 22,100 | 17,900 | 7,900 | 5,800 |
| D (See Note 1) | 12,500 | 8,800 | 6,800 | 3,800 | 2,900 |
| TOTAL | 91,400 | 64,500 | 49,300 | 27,400 | 21,000 |
| DIRECT BENEFITS | | $26,900 | $42,100 | $64,000 | $70,400 |
| TOTAL BENEFITS (See Note 2) | | $51,100 | $80,000 | $121,600 | $133,800 |




PROBABILITY OF EQUALLING OR EXCEEDING DESIGNATED DAMAGE IN ANY ONE YEAR

*To express above probability as "percent chance", multiply the above figures by 100.*

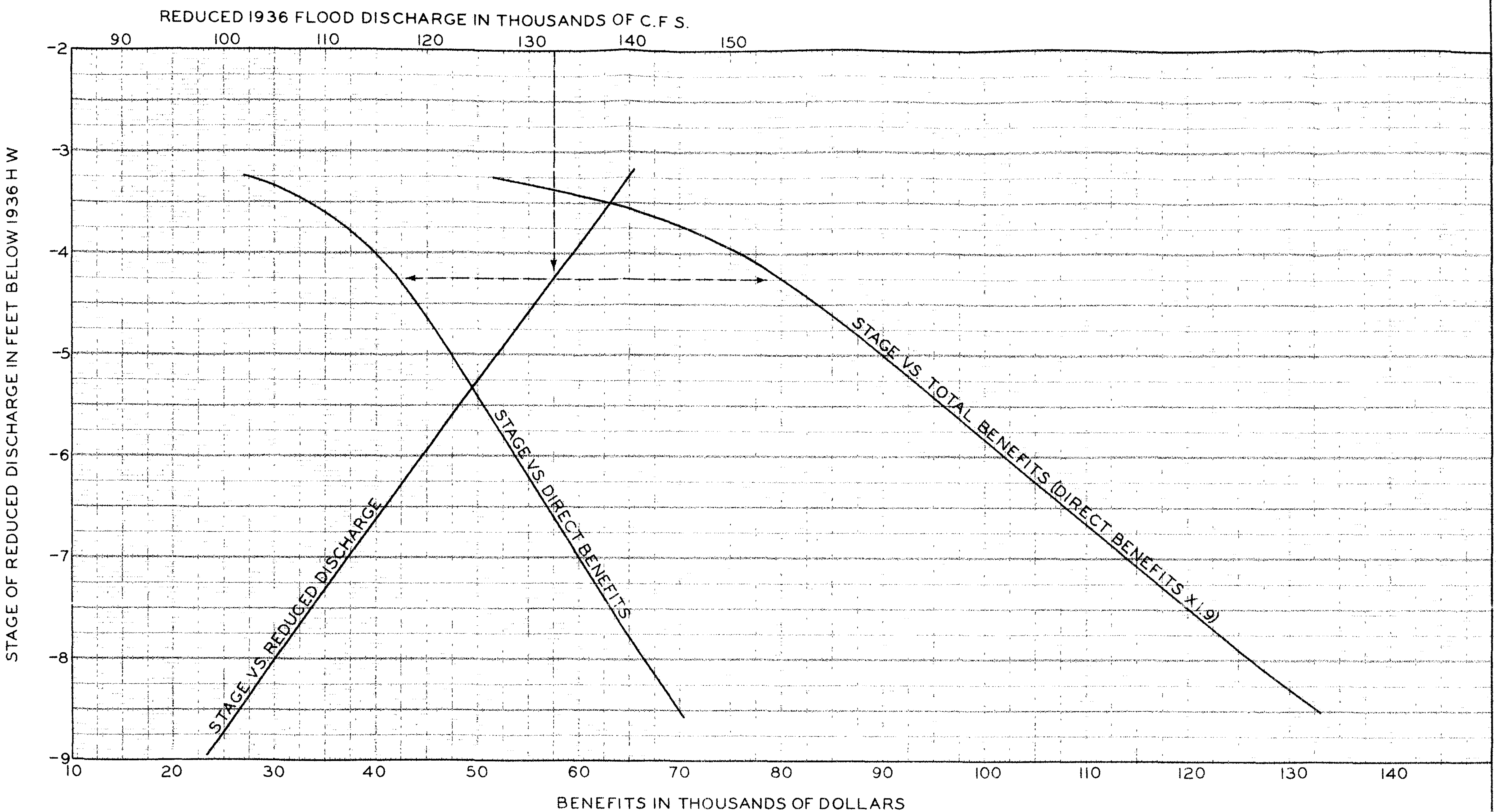
*Note 1 - Same percent of damage reduction resulting for sections A+B+C was assumed for section D.*

*Note 2 - Total benefits equal direct benefits multiplied by indirect damage factor 1.9.*

MERRIMACK VALLEY FLOOD CONTROL

**DAMAGE - FREQUENCY RELATIONS**

MERRIMACK RIVER - LOWER LOWELL REACH - M3
U.S. ENGINEER OFFICE, BOSTON, MASS.
APRIL, 1940 FILE NO. M100-40/25




MERRIMACK VALLEY FLOOD CONTROL

**STAGE-DISCHARGE AND**

**STAGE-BENEFITS CURVES**

MERRIMACK RIVER-LOWER LOWELL REACH-M-3

U.S. ENGINEER OFFICE BOSTON, MASS.

APRIL 1940 FILE NO. M100-40/26

PLATE B 6